Reactor design issues for different applications of the biological water gas shift process

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Current hydrogen production technology consists of either reforming or partially oxidizing natural gas to produce “synthesis gas”, which contains a mixture of hydrogen (H_2), carbon monoxide (CO), and carbon dioxide (CO_2). The extent to which the CO concentration in the synthesis gas must be reduced is a function of the desired end use of the gas stream. For example, different types of fuel cells have different levels of sensitivity to CO, which acts as a poison to the cell electrodes. They type of fuel cell in use will dictate the maximum permissible concentration of CO (often as low as 10ppmv).

To remove the CO, and simultaneously produce even more H_2, the water-gas shift reaction is employed, in which CO is oxidized to carbon dioxide (CO_2) while simultaneously water (H_2O) is reduced to H_2. The overall reaction stoichiometry of this reversible reaction is:

$$CO + H_2O \overset{K}{\leftrightarrow} CO_2 + H_2 \qquad (1)$$

The current “state-of-the-art” water-gas shift technology consists of a two-stage, high temperature, high-pressure catalytic process. The reaction is equilibrium-limited at the temperatures required for this catalytic process to operate sufficiently rapidly, so a multi-step reaction is required. Often times a pressure-swing adsorption (PSA) step is also required.

NREL researchers have isolated a number of photosynthetic bacteria that can perform the water-gas shift reaction at ambient temperature and pressure. Although the bacteria are photosynthetic, this reaction occurs equally rapidly in the presence and absence of illumination. If this process is used to treat a biomass-derived synthesis gas stream, the resulting gas stream, now enriched in hydrogen, could be considered completely renewable.

Previous work has indicated that mass transfer of gaseous CO into the aqueous phase of the bacteria is the rate-limiting step of the process. We have performed a number of experiments to determine the extent of mass-transfer limitation, and to investigate bioreactor designs that may provide significantly higher overall reaction rates than are currently possible.

In this presentation, we will discuss potential applications of the biological water-gas shift reaction, and discuss how the scale of the gas flow to be treated and the required purity of the end product affect the optimal biological reactor design.